Research Reports

CT Angiography in Acute Ischemic Stroke
Preliminary Results

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Background and Purpose—We sought to evaluate the ability of CT angiography (CTA) to determine vessel occlusion before acute stroke treatment and to predict its impact on patient outcome.

Methods—Consecutive patients with acute focal neurological deficits received immediate brain CTA. Occlusion on CTA was correlated with other neuroimaging studies and clinical outcome.

Results—Diagnostic CTA was obtained in 54 patients: catheter angiography (digital subtraction angiography) confirmed the CTA findings in 12 of 14 patients (86%). CTA results were consistent with at least 1 other neuroimaging study in 40 of 50 patients (80%). Patients with occlusion on CTA had significantly worse discharge National Institutes of Health Stroke Scale (NIHSS) score (mean 14.3 versus 4.5, P=0.0023). In multivariate analysis, both CTA-determined presence of occlusion and admission NIHSS score were independent predictors of clinical outcome.

Conclusions—In our study there was good agreement between acute CTA interpretation and subsequent imaging studies. CTA evidence of occlusion correlated strongly and independently with poor clinical outcome. CTA provides relevant data regarding vessel patency in acute stroke, which may be of value in selecting patients for aggressive treatment.

Key Words: cerebrovascular disorders • neurology • radiology • stroke

Intravenous recombinant tissue plasminogen activator (tPA) for acute ischemic stroke has been shown to be effective within 3 hours of onset, but criticism has been levied against this mode of treatment because it fails to document vessel occlusion at the time of treatment.1 Previous studies clearly indicate that close to 30% of patients with symptoms of major stroke have no demonstrable vessel occlusion on digital subtraction angiography (DSA) performed within a few hours of onset.2–4 A method for rapidly and reliably confirming intracranial vessel occlusion before thrombolytic treatment is desirable. CT angiography (CTA) is potentially useful for this purpose: previous studies evaluating CTA in acute stroke have demonstrated its feasibility and have shown good correlation with other vascular imaging modalities.5–8 We sought to provide further data on the accuracy of CTA in acute stroke and to investigate its ability to predict clinical outcome.

Subjects and Methods
Sequential patients presenting with acute symptoms suggesting cerebral ischemia received a nonenhanced brain CT followed immediately by CTA of the circle of Willis. CTA was performed as a clinically indicated study when, in the opinion of the treating physician, an immediate assessment of vascular status could assist in making acute treatment decisions. Most but not all patients were candidates for intravenous or intra-arterial thrombolysis; a few were considered for immediate anticoagulation with heparin. Clinical assessment and laboratory testing proceeded simultaneously with CTA data acquisition and reconstruction to avoid delays in treatment.

Imaging was performed on a General Electric Hi Speed Advantage single-slice spiral CT scanner with an intravenous bolus of 100 mL of radiographic contrast agent administered via a power injector. Scanning was timed to permit imaging proximal and distal branches of the circle of Willis; extracranial vessels were not imaged. Combined injection and scanning time took <5 minutes. Image reconstruction was performed at the control console immediately after completion of the injection. Axial, coronal, and sagittal projections of the intracranial vasculature were generated with the use of multiprojection volume reconstruction requiring approximately 5 minutes per plane. Images were available immediately after reconstruction, and the treating neurologist always reviewed these before making treatment decisions.

Intravenous tPA within 3 hours was administered by a stroke neurologist (P.V. or S.S.) to patients who qualified for this treatment according to National Institute of Neurological Disorders and Stroke (NINDS) criteria. Treatment decisions were based primarily on the clinical evaluation; CTA results provided supplemental information that aided but did not determine the treatment chosen. Patients not meeting NINDS criteria for intravenous tPA who could potentially benefit from thrombolysis received immediate DSA and microcatheter-directed intra-arterial tPA if an appropriate vascular occlusion was identified.

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A, CTA performed 4 hours after symptom onset, demonstrating occlusion of distal left middle cerebral artery stem with collateral supply via pial vessels to distal middle cerebral artery branches. B, DSA performed immediately after CTA and resembling it closely, including identical site of occlusion and evidence of pial collateral supply to distal middle cerebral artery branches.

An experienced neuroradiologist (L.N.T.) not involved in the acute care of the patients but aware of presenting clinical signs and blinded to other neuroimaging studies identified the presence of a vascular obstruction on CTA consistent with the patient’s symptoms. Both vascular occlusions and high-grade stenoses in the appropriate territory were considered equivalent in this study. The patients’ neurological deficits were measured by a certified rater using the National Institutes of Health Stroke Scale (NIHSS) score at the time of presentation and discharge.

**Results**

CTA was successfully completed in 54 patients. Time from symptom onset to CTA was <6 hours in 38 patients (70%), between 6 and 12 hours in 14 patients (26%), and uncertain in 2 patients (4%). Occlusion or high-grade stenosis accounting for the patient’s symptoms was identified on CTA by the study neuroradiologist in 30 patients: 11 in the middle cerebral artery stem (M1 segment), 9 in a main middle cerebral artery branch (M2 segment), 7 in the distal internal carotid artery, and 1 each in the vertebral, posterior cerebral, and anterior cerebral arteries.

Eight patients with evidence of occlusion on CTA received immediate intravenous tPA according to NINDS protocol. Nine others received immediate DSA for possible thrombolysis; CTA interpretation made at presentation was confirmed by DSA in all 9 patients. One of these patients had bilateral vertebral artery occlusions that were correctly identified on CTA at presentation but were missed when the CTA was read for study purposes. A typical example is shown in the Figure in a patient with an M1 occlusion demonstrated on a coronal CTA projection and confirmed by DSA performed immediately afterward. The CTA is able to clearly demonstrate the occlusion as well as the collateral supply to the occluded vessel via the pial circulation.

Intra-arterial thrombolysis was administered to 7 patients who underwent immediate DSA. Five other patients underwent DSA subacutely for diagnostic purposes. Overall, CTA detection of vessel occlusion corresponded with acute or subacute DSA results in 12 of 14 cases (86%), with correlation coefficient $r=0.701$, sensitivity of 82%, and specificity of 100%.

MR angiography (MRA) was performed in 12 patients in the subacute period; this confirmed the CTA findings in 9 cases (75%). Subsequent brain imaging studies (CT or MRI) were done in 50 patients; 40 of 50 (80%) of these were consistent with the CTA results by demonstrating an infarct in the vascular distribution corresponding to a CTA occlusion or absence of infarct when CTA showed no occlusion. CTA determination of occlusion was found to be consistent with at least 1 other study (DSA, MRA, or follow-up brain imaging) in 43 of 51 patients (84%), with correlation coefficient $r=0.59$, sensitivity of 87%, and specificity of 84%.

Clinical outcome was worse when CTA showed occlusion: mean discharge NIHSS score was 14.3 versus 4.5 in the absence of occlusion ($P=0.0023$, $t$ test). Since outcome might be affected by treatment, this analysis was repeated while censoring the 11 patients who received thrombolytic treatment and had definite or possible recanalization. The results were essentially unchanged, with mean discharge NIHSS score of 13.5 versus 2.8 ($P=0.0017$, $t$ test).

In univariate analysis, both CTA evidence of vessel occlusion and admission NIHSS score correlated with clinical outcome measured by discharge NIHSS score ($r=0.51$ and $r=0.65$, respectively; $P=0.0001$ for both, Spearman correlation coefficients). In multivariate regression analysis, both the admission NIHSS score and presence of occlusion on CTA were independent predictors of discharge NIHSS score.

**Discussion**

CTA evidence of vessel occlusion as determined by the treating physicians was in agreement with immediate catheter angiography in 9 of 9 cases (100%). Previous studies comparing CTA with conventional angiography by Knauth et al\(^9\) showed agreement in 11 of 11 patients (100%), by Brandt et al\(^6\) in 6 of 6 (100%), by Wilderum et al\(^7\) in 6 of 7 (86%), and by Shrier et al\(^8\) in 27 of 28 patients (96%). Our results are thus quite consistent with other studies and show good correlation of CTA results with immediate catheter angiography.

When CTA is compared with all DSAs, both acute and subacute, agreement is still good (86%) despite the fact that subacute angiograms might differ from the acute CTA because of spontaneous recanalization or subsequent reocclusion. When CTA is compared with all possible follow-up testing (DSA, MRA, and brain imaging studies), there is overall confirmation of the CTA reading in 80% of cases. We acknowledge the significant limitations inherent in using indirect and delayed studies as confirmation of CTA results.
An important finding of this study is that the presence of occlusion on CTA at presentation correlates strongly and independently with clinical outcome. Censoring patients receiving successful thrombolysis does not affect this association, supporting the interpretation that the poor outcomes reflect the natural history of acutely occluded vessels. Because CTA results are independent predictors of clinical outcome, they provide data that can supplement the clinical examination. These predictions are potentially useful in making treatment decisions involving thrombolysis. Further work in this area should aim at confirming these associations and identifying CTA characteristics that may help in selecting patients for intravenous or intra-arterial thrombolysis.

References
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